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METHODS OF SAMPLING SCORPION POPULATIONS

By
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ABSTRACT: The use of pitfall traps as a method of sampling scorpion populations is discussed and compared with other methods. The catches of covered and uncovered traps were statistically compared, covered traps being found to collect a significantly larger number of specimens. The influence of specimen removal on long term trap catches was studied. Specimen removal did not significantly alter the number of scorpions captured by traps over a 22 week interval, under the removal pressure employed. As a sampling tool, pit traps were concluded to have many advantages over methods such as rock rolling, and burrow excavation. However, they lack some of the advantages of the ultraviolet detection method.

INTRODUCTION

Scorpions have traditionally been studied by turning surface objects such as boards, rocks, bark, and trash. Specimens thus obtained are generally few in number and yield data which are often difficult to interpret from an ecological point of view. Even more important, some species are rarely encountered because of specialized ways of life such as burrowing.

Recently, more practical and useful means of studying and collecting scorpions have been used with success: trapping and ultraviolet detection. The purpose of this paper is to report on the pitfall trapping method and to compare it with other methods in use.

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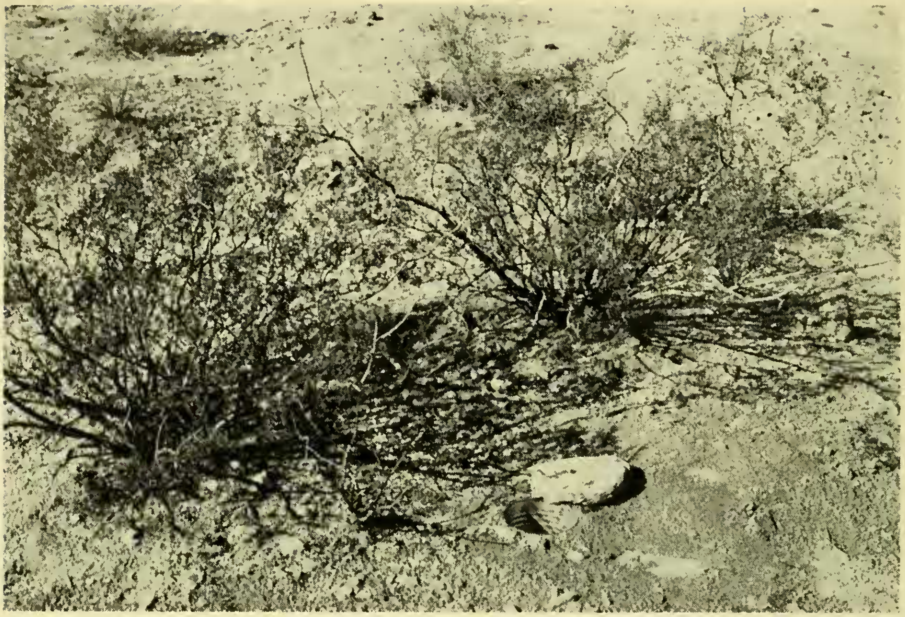

Figure 1. Pitfall trap used in this study. Notice how trap is set with upper lip flush with the ground surface. The rock is used to cover the opening of the trap at all times.

Materials and Methods

Selection of field study area. An area located at the eastern end of Phoenix South Mountain (30° 26′ N. Lat., 112° 01′ W. Long.), Maricopa County, Arizona, was selected for the field study. This area is about 1 mile south of the town of Guadalupe. Selection of this study area involved the following considerations: the ecology was relatively undisturbed; access was convenient; and the scorpion fauna was abundant and diverse.

Sampling method. Sampling was carried out exclusively by means of unbaited pitfall traps, which were permanently set in their respective locations for the duration of the study. Number-10 food cans served as traps. These were deep enough to prevent the escape of even the largest scorpion species, and to retain the captured scorpions well below the environmental extremes occurring on the soil surface. Each can was buried so that its open end was flush with the ground surface, and was covered by a suitably sized rock or masonite square (fig. 1).

Traps were checked twice each week, except when they were checked on a daily schedule (when testing the effect of trap cover type on catch numbers).

The 100 unbaited traps used in this study were equally distributed in two adjacent areas. In each area, 50 traps were linearly arranged along a "U-shaped"

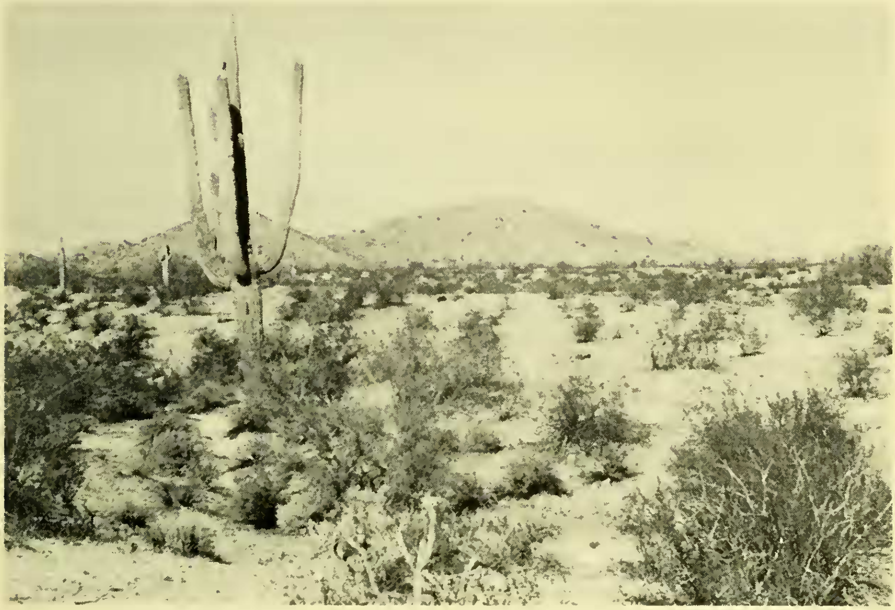

Figure 2. View of study area at northeastern end of Phoenix South Mountain, Maricopa County, Arizona.

line transect. All traps were spaced along the transect at 9 meter intervals by pacing.

Throughout the course of the study, trap maintenance was carried out as needed. This maintenance included removal of soil and animals from traps, removal of water after rain, keeping the lip of the trap flush with the soil surface, replacement of traps as they became rusty, and keeping trap sides clean and smooth in order to prevent escapes.

Results

Description of study area. Phoenix South Mountain is a long, northeast to southwest oriented mountain range, isolated from neighboring mountains by expanses of flat desert basin. At the eastern foot of the mountain the elevation is 381 meters above sea level while the highest peak reaches an elevation of 759 meters above sea level. The mountain is rugged, rocky, and dissected by many irregular valleys and canyons. The trap areas were located in the open desert at the northeast end of the mountain. The town of Guadalupe was approximately 1 mile to the north, and the mountain was about 0.5 mile to the west. The vegetation of this area can be best characterized as belonging to the *Larrea-Franseria* association of the Lower Colorado Valley division of the Sonoran desert (Shreve, 1951).

The terrain was basically flat and smooth but was occasionally divided by shallow washes. The soils had a texture similar to sandy loam, but were well compacted and often stony. In most places a hard, subsurface, mineralized layer was present.

The vegetation was dominated by creosote bush (*Larrea tridentata* (DeCandolle) Coville) and bur-sage (*Franseria deltoidea* Torrey) but, paloverde (*Cercidium microphyllum* (Torrey) Rose and Johnston), ironwood (*Olneya tesota* Gray), white bur-sage (*Franseria dumosa* Gray), Mormon tea (*Ephedra* species), and saguaro (*Carnegiea gigantea* (Engelmann) Britton and Rose) also occurred, although in less abundance.

This area was relatively homogeneous in regard to the flora because of the clear dominance of *Larrea*, and in regard to terrain because of its locations away from the mountain (fig. 2).

Climatic studies showed that air temperature extremes from –7° to 47° centigrade occurred during the last 28 years (Kangieser, 1966). Lowest temperatures occurred in December and January, while highest temperatures occurred during June, July, and August. Rainfall was very irregular from year to year, but generally was greatest in August. During the last 28 years, August rainfall varied from 0.18 to 14.1 centimeters with an average of 2.85 centimeters. May and June were the months of lowest rainfall. During the last 28 years, monthly rainfall for these months varied from 0.00 to 2.41 centimeters with an average of 0.33 centimeters in May and 0.23 centimeters in June. All weather and climatic data were gathered at the Phoenix Sky Harbor Airport approximately 5 miles away from the study area.

SCORPION POPULATIONS SAMPLED BY THE TRAPS. A total of 607 scorpions, from four species of the family Vejovidae were captured in the 100 traps. These were: *Hadrurus arizonensis* (Ewing), *Vejovis confusus* Stahnke, *Vejovis spinigerus* (Wood), and *Vejovis stahnkei* Gertsch & Soleglad. Only two of these species were collected in large enough numbers to permit analysis: *H. arizonensis* with 156 specimens and *V. confusus* with 445 specimens.

THE INFLUENCE OF TRAP COVERS ON SCORPION CAPTURE BY PITFALL TRAPS. To determine if trap covers influenced the numbers and kinds of scorpions captured by the pitfalls, the 100 traps were operationally established to test three cover variables. These three variables were: rock covers, masonite square covers, and no covers. Each of the three variables were sampled by 33 traps set in a linearly alternating pattern. (Data from trap 100 were not used in this analysis.) The rocks and masonite squares used as trap covers each covered a ground surface approximating 900 square centimeters. All traps were checked every morning to minimize trap predation, and heat induced death.

The assumption was made that if trap covers had no influence on the effectiveness of the pitfalls to capture scorpions, then essentially the same numbers of scorpions should be collected by each of the three pooled samples. These

TABLE 1. *The influence of trap covers on scorpion capture. The captures of traps covered by rocks, masonite, and with no covers were compared by Chi Square Analysis. Each trap situation was represented by 33 traps. Data were gathered from 1 August 1966 through 4 September 1966.*

	Observed Numbers	*Expected Numbers*	*Sample Size*	*D. F.*	X^2	*P*
H. arizonensis						
rock	12	9.3	28	2	6.54	$P < 0.05$
masonite	13	9.3				
no cover	3	9.3				
V. confusus						
rock	23	14.6	44	2	17.07	$P < 0.01$
masonite	19	14.6				
no cover	2	14.6				
Pooled						
rock	35	24	72	2	22.82	$P < 0.01$
masonite	32	24				
no cover	5	24				
Heterogeneity:				2	0.79	$0.70 > P > 0.50$

data were gathered from 1 August 1966 through 4 September 1966, and were analyzed by Chi Square analysis.

Analysis of the capture of 28 specimens of *H. arizonensis* showed that the different trap types did not sample this species in a random manner ($P < 0.05$). Traps with rock and masonite covers were essentially equivalent in numbers of scorpions captured while the traps with no covers had a distinctly lower catch (table 1).

Analysis of the capture of 44 specimens of *V. confusus* showed that the different trap types did not sample this species in a random manner ($P < 0.01$). Traps with rock and masonite covers were essentially equivalent in catch numbers, while the uncovered traps captured strikingly fewer *V. confusus* (table 1).

It was concluded that covered traps captured a significantly greater number of scorpions than those with no covers. No significant difference was apparent between the catches of the traps covered by rocks and those covered by masonite squares. Both species reacted to the three cover situations in a homogeneous manner, as judged by the nonsignificant heterogeneity Chi Square (table 1).

THE INFLUENCE OF SCORPION REMOVAL ON CATCH NUMBERS. To determine if scorpion removal had any effect on subsequent catch numbers, the catches of the two equivalent, 50-trap areas were compared. In one area all captured scorpions were removed while all captured scorpions were recorded and released in the other. This study was carried out from 24 April 1966 throughout 9 October 1966. It was expected that the two areas would not differ significantly un-

Table 2. *The effect of permanent scorpion removal on catch numbers. The catches in an area with permanent specimen removal were compared with those of an area in which all scorpions were released. Each area was sampled by 50 equivalent and linearly arranged traps from 24 April 1966 through 9 October 1966. Data were analyzed by Chi Square Analysis using Yates' Correction for Continuity.*

	Observed Numbers	*Expected Numbers*	*Sample Size*	*D. F.*	X^2	*P*
H. arizonensis						
removal	73	78	156	1	0.520	$0.50 > P > 0.30$
release	83	78				
V. confusus						
removal	217	222.5	445	1	0.406	$0.70 > P > 0.50$
release	228	222.5				

less removal affected the probability of future catches. If removal were to actually reduce the probability of future catches by a trap, then it would be expected that the trap area employing scorpion removal should show a decreased catch when pooled catches of several months were compared.

Analysis of 156 specimens of *H. arizonensis* and 445 of *V. confusus* revealed that no significant difference occurred in the catch numbers of the removal area as compared with those of the release area (table 2). It was, therefore, concluded that specimen removal did not significantly alter the probability of future captures for either species under the removal pressure employed.

Discussion and Conclusions

Effectiveness of pitfall traps for sampling scorpions. That 100 traps collected 607 scorpions of four species in 5½ months was impressive evidence that unbaited pitfalls were effective devices for the sampling of scorpion populations. In the area sampled, it would have been virtually impossible to obtain samples of this magnitude by turning surface objects since such items are not commonly encountered in this habitat. In addition to obtaining scorpion samples of sizable numbers, use of these traps permitted the gathering of standardized numerical data which could be partitioned into suitable samples for statistical comparisons.

The traps were significantly more effective devices for sampling scorpion populations when they were covered than when uncovered. Whether this was because the scorpions sought shelter under the trap covers or because they were able to detect and avoid uncovered traps was not determined. There was no significant difference between the numbers captured in traps covered by masonite and those covered by rocks. Perhaps any kind of cover would serve as a good trap cover.

The area in which all scorpions were permanently removed yielded essentially the same numbers of scorpions of each species, as the nearby area in which all scorpions were released after capture. This clearly indicated that permanent specimen removal did not significantly affect subsequent catches. Probably the linear arrangement and spacing of traps created a situation in which any one unit area was not under significantly heavy removal pressure to reduce the catches. Theoretically then, as specimens were removed, others must have moved in to occupy the available space. The populations may also have been so large that the numbers removed were not detectable. Both of these mechanisms appeared to be in operation.

More species of scorpions were collected by the traps than were predicted to occur in the area by preliminary search under rocks and other available surface objects. Also, the relative numbers of each species captured appeared to represent the composition of the natural scorpion community of the habitat (judging by similar relative numbers observed with the ultraviolet method).

Advantages of the pitfall method. The three main advantages of using the pitfall method are: large sample sizes may be obtained; sampling is continuous whether or not an observer is present in the field; and trap data may be partitioned into various equivalent units for experimental analysis. Specialized aspects of the life history may also be revealed by analysis of the trap data (Williams, 1966).

Disadvantages of the pitfall method. The pitfall method is not without disadvantages. The installation of these traps often requires much time and work, especially in areas characterized by well compacted, mineralized, or stony soils. Soils may be so rocky or thin that trap establishment is virtually impossible.

Scorpions also appear to have a patchy spatial dispersion. A series of traps might, therefore, be established in an area with a very small or no scorpion population, while an adjacent slope might contain a very dense population.

Trap checking and maintenance requires the expenditure of considerable time. For data to have analytical value, a rigid checking schedule must be set and maintained throughout the study. The traps are constantly in need of maintenance. Many kinds of organisms are captured in addition to scorpions. These must be continually removed to prevent the attraction of ants, necrophagous animals, and predators such as foxes and coyotes. If care is not taken, coyotes may learn to check the trap lines each night in search of food (including scorpions).

Comparison with other sampling methods. Traditionally three methods have been used to sample scorpion populations: turning objects on the ground surface (often called "rock rolling"), location of burrows followed by excavation of the inhabitant, and peeling loose bark from trees. In addition, two newer methods have recently been used with much success: pitfall trapping (as discussed in this paper), and ultraviolet detection. Each method has its advantages and disadvantages. Any good field study will probably make use of all these methods to some extent, while depending more on the most appropriate methods for the basis of the data gathering.

The primary advantage of rock rolling as a sampling method is its simplicity. No special equipment is necessary. One can quickly cover an area, collecting enough specimens to permit a diagnostic analysis of the scorpion populations present and their relative abundances. Unfortunately the numbers of specimens gathered are often small, therefore, rare species, or species with specialized life histories, may not be represented in the sample. During certain times of the year, specimens might not be detected by rock rolling because diurnal ground temperatures may reach the lethal range. Also, some habitats, such as sand dunes, cannot be sampled by rock rolling because of the conspicuous lack of surface cover objects.

Burrow detection methods have many disadvantages. Excavation of the burrow is necessary to identify the inhabitant. This is disadvantageous in that extensive excavation is often much hard work, takes much time, and may severely disturb the ecology of an area being studied. Also, generally only one or two species will be detected by burrow excavation in an area which may be occupied by six or seven species.

Bark peeling as a method of sampling scorpions makes use of the habit of certain species of scorpions to seek shelter under bark. Members of the genus *Centruroides*, for example, are well known for their affinities toward tree climbing, and for their dense aggregations under bark in some habitats. Although this method may yield large numbers of specimens in a short time, only a few species in an area will normally be detected because of different habitat affinities.

The ultraviolet detection method appears to have great promise for scorpion sampling. This method takes advantage of the property of the scorpion cuticle to convert ultraviolet radiation into visible light. Using this method, an observer walks through a suspected scorpion habitat at night with a portable ultraviolet light. Any scorpion within range on an exposed surface is easily detected by the bright greenish-yellow fluorescence of its cuticle against the dark background. As an example of the effectiveness of this technique, the author and Mont A. Cazier recently collected some 2000 scorpions from a California sand-dune habitat in less than 4 hours. At one time, 17 specimens were seen glowing in the field of one ultraviolet lamp. The ultraviolet technique was also used with success by Williams and Hadley (1967) to survey the scorpion fauna of a coastal sand-dune community. This method of detection has since been refined by these authors and is currently being used to study activity patterns, nocturnal surface behavior, and spatial dispersion of scorpions.

The effective range of an ultraviolet lamp varies from a few feet to around 50 feet, depending on factors such as the wave length generated, filters, power supply, and condition of the battery. Generally the longer wave length units have a greater effective range, but have the disadvantage of requiring a larger and heavier power supply and battery. The filament of the commercially available units generates not only ultraviolet, but visible wave lengths. The distraction of the visible light is, however, controlled by the use of blue filters. Selection of a lamp requires a compromise of several factors such as adequate range, portability, effective life of battery and price.

Ultraviolet observation may be easily designed to yield data which are standardized for statistical analysis. For example, a line transect of a given length can be walked at night and all specimens glowing within range of the light can be counted and pooled together to yield one repeatable sample. This sample, therefore, results in a count of so many specimens (of each species) per belt transect of a given surface area (width of transect is determined by the range of the lamp). Another method would be to walk randomly through an area and count specimens per unit time of search.

When using ultraviolet detection, caution must always be taken to prevent looking into the lamp, as ultraviolet light can cause severe damage to the retina of the eye. One must also be careful of making unfortunate contacts with venomous animals such as rattlesnakes.

The potential of the ultraviolet method is impressive. Its main values are that it can be used effectively even over short time spans, it causes minimal ecological disturbance, and it yields large sample sizes if and when scorpions are active on the ground surface.

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